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# MUSIC-TYPE ALGORITHM FOR EDDY-CURRENT NONDESTRUCTIVE EVALUATION OF SMALL DEFECTS IN METAL PLATES

Tommy HENRIKSSON, Marc LAMBERT and Dominique LESSELIER

Département de recherche en électromagnétisme, Laboratoire des Signaux et Systèmes/Supèlec, 3 rue Joliot-Curie, 91192 Gif-sur-Yvette Cedex, France

Abstract

Eddy-Current nondestructive evaluation of metal plates is of interest in a wide range of applications such as quality control in production lines or in-service inspection of industrial facilities. Both the tube and plate configuration have been studied earlier, by using different iterative optimization processes [1, 2]. These solutions are computation-heavy and time-consuming, and in many practical situations the processing time is a critical criterion, thus a quicker non-iterative method might be more appropriate. An alternative method could be to solve the computation-heavy inverse problem by interpolation in an off-line database as is presented in [3]. In general, only the position and size of the defect is of interest in the nondestructive evaluation. In this case a linearized non-iterative method could be suitable, since it can be implemented with a quasi-real-time functionality.

In this paper we are investigating a non-iterative MUSIC (MUltiple SIgnal Classification)-type algorithm for the detection (position and size) of small void defects inside a conducting plate. The method has been presented mathematically in a general case in [4], and has been successfully developed for the detection of one or several spherical defects in a dielectric half-space, in the MHz band [5]. However, to the knowledge of the authors this is the first time the technique is used in the lower frequency band (kHz) for eddy-current testing, to retrieve small void defects inside a conducting plate. Herein, a situation with one or several spherical void defects inside such plate is considered, arranged as a free space region (region 1) above a conducting plate (region 2). The plate is considered non-magnetic ($\mu_2=\mu_0$) and linear isotropic with the complex permittivity $\varepsilon_2 = \frac{-\sigma_2}{i\omega}$ when a time-dependency $e^{-i\omega t}$ is applied. An array of transmitting/receiving bobine coil sensors is located inside region 1 and placed parallel to the conducting plate. The sensors are assumed to be small bobine coils, which can be approximated as an array of magnetic dipoles.

A full description of MUSIC algorithm is found in [4, 5]. Briefly, it is based on the asymptotic formulation of the scattered field, where the radius of the defect is assumed to be small compared to the skin depth. In this situation the asymptotic formula is then given by

$$H^{(n)}(r) - H_0^{(n)}(r) = \alpha^3 \sum_{j=1}^{m} \left[\sigma_2 \nabla' \times \mathrm{G}^{\mathrm{me}}(\mathrm{r}, x_j) \cdot \mathrm{M}\left(\frac{\sigma_j}{\sigma_2}, \mathrm{B}_j\right) \mathrm{E}_0^{(n)}(x_j)\right],$$

where M is the polarization tensor and $\sigma_j$ is the conductivity of the *jth* inclusion. By transforming the Green's function $\mathrm{G}^{\mathrm{me}}(\mathrm{r}, x_j)$ into receiver and transmitter Green's functions $G_r^{me}(\mathrm{r}, x_j) = G_t^{me}(x_j, \mathrm{r})$, the multistatic response (MSR) matrix A can be formed as

$$A = \sum_{j=1}^{m} \mathrm{G}_{\mathrm{r}}^{\mathrm{me}}(x_j) \mathrm{M}_j \mathrm{G}_{\mathrm{t}}^{\mathrm{me}}(x_j) = \mathrm{U}\Sigma\mathrm{V}^*,$$

where a Singular Value Decomposition (SVD) has been applied. It has been shown that the singular value pattern of the MSR matrix is dependent on the defect's position and size

together with sensor configuration. By appropriately truncating the singular values to minimize effects from noise, the defects can be imaged by using an identifier with the orthogonal projections of the MSR matrix, as shown in [4, 5].

In this paper the developed Eddy-Current MUSIC-type algorithm is presented. First, the asymptotic formulation is validated by comparing the results with the nondestructive evaluation simulation tool CIVA in realistic cases. Next, the singular value pattern is investigated, for several defect and sensor arrangements, together with images of the defects. Since this is the first investigation of a MUSIC-type algorithm for Eddy-Current testing only simulated data from the CIVA platform will be considered. However, in the prospective a deeper experimental based investigation is proposed.

References


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